Attachment H

Proposal # 2001- C-212 (office use only)

PSP Cover Sheet

Proposal Title: **Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology**

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Amount of funding requested: $399,980.00

Cost share partners ___Yes _X_No
Identify partners and amount contributed by each:

Indicate the Topic for which you are applying (Check only one box).

Natural Flow Regimes
Nonnative Invasive Species
X Channel Dynamics/Sediment Transport
Flood Management
Shallow Water Tidal/Marsh Habitat
Contaminants
Beyond the Riparian Corridor
Local Watershed Stewardship
Environmental Education
Special Status Species Surveys and Studies
Fishery Monitoring Assessment and Research
Fish Screens

What County or Counties is the project located in? Butte, Colusa, Glenn, Sacramento, Shasta, Sutter, Tehama, Yolo

What CALFED ecozone is the project located in? # 3, Sacramento River ecological zone; also #4, North Sacramento Valley ecological zone (along the Sacramento River floodplain)

Indicate the type of applicant (check one box only):

State agency
Public/Non-profit joint venture
Local government/district
University
Other:
Federal agency
Non-Profit
Tribes
X Private party

Indicate the primary species which the proposal addresses (Check all that apply):

San Joaquin and East-side Delta tributaries fall-run chinook salmon

X Winter-run chinook salmon
X Spring-run chinook salmon
X Late-fall run chinook salmon
X Fall-run chinook salmon
Delta Smelt
X Longfin smelt
X Splittail
X Steelhead trout
X Green sturgeon
Striped bass
X White sturgeon
X All chinook species
Waterfowl and shorebirds
X All anadromous salmonids
X Migratory birds
X American shad
Other listed T/E species:

Indicate the type of project (check only one box):

X Research/monitoring
Watershed planning
Pilot/demo project
Education
Full scale implementation

Is this a next-phase of an ongoing project Yes ___ No_X_
Have you received CALFED funding before? Yes ___ No _X_
If yes, list project title and CALFED number:

Have you received funding from CVPIA before Yes ___ No _X__
If yes, list CVPIA program providing funding, project title and CVPIA number:

By signing below, the applicant declares the following:

- The truthfulness of all representations in their proposal;
- The individual signing the form is entitled to submit the application of behalf of the applicant (if the applicant is an entity or organization); and
- The person submitting the application has read and understood the conflict of interest and confidentiality discussion on the PSP (Section 2.4) and waives any and all rights of privacy and confidentiality of the proposal on behalf of the applicant to the extent as provided in the Section.

Michael Singer

Signature of applicant

B. EXECUTIVE SUMMARY

Title: Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

Amount Requested: $ 399,980

Applicant Name: Michael Singer, Donald Bren School of Environmental Science & Management
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Summary: Riparian habitats are influenced by configurations of stored sediment into channel and floodplain morphology that form a physical template upon which ecology develops. This topographic complexity in the riparian corridor is affected by hydrology, sediment transport, boundary conditions, and the history of channel change. In order to aid in habitat restoration efforts we propose to research the influence of these factors on river channel and floodplain morphology in the Sacramento River valley. We will investigate the relative effects of the following Ecosystem Restoration Program (ERP) restoration strategies on channel and floodplain evolution: streamflow alterations, changes in sediment supply, and channel modifications.

We propose to develop a mathematical model of flow and sediment routing in the channel and floodplain of the mainstem Sacramento River that would provide the predictive capability necessary for analyzing management alternatives. It will be our goal to model both the manipulable and the natural influences on the sediment budget and their consequences for habitat creation and evolution.

As CALFED embarks upon a program of significant riparian-zone management, it becomes important to understand the processes which govern channel and floodplain morphology. We would utilize this opportunity to investigate the following questions.

- How will restoration measures involving changes in flow modification, changes in sediment supply, and channel alteration affect channel and floodplain morphology on the reach-scale?
- How will changes in local channel and floodplain morphology affect the sediment balance at the basin-scale?

In order to validate our modeling capability we will also address the following historical question.

- What does empirical evidence tell us about changes in sediment and hydrologic flux regimes in the past and what were the resulting morphological changes?

There exist for the Sacramento River basin a number of historical single-purpose datasets (e.g. sediment transport, streamflow, channel cross-sections) and a long historical record of perturbations to the system (e.g. aerial photographs). Yet, there are no comprehensive, quantitative process studies of hydrology and sediment transport as they relate to resultant channel changes in the Sacramento basin. Our aim is to synthesize and integrate these data to construct a supply-process-form model with a minimum amount of calibration, that could be applied to predict river adjustment under different land-use scenarios.

We will develop a sediment routing model which includes the capacity for assessing bank and bed erosion, variations in channel width, and overbank flooding and sedimentation. The model will be driven by stochastically-generated flow events in the Sacramento River basin. Given a particular restoration scenario, the model will provide output describing probable effects on the sediment budget on the basin-scale and "most likely" resultant channel and floodplain morphology on the reach-scale. It will allow policymakers to anticipate resultant morphological conditions relevant to habitat restoration and flood control strategies such as restoration of "natural" valley streamflow regimes, gravel feeding below dams, or setback levees [*ERP*, Vol.1, p.42-43].

C. PROJECT DESCRIPTION

1. Statement of the Problem

Riparian habitats are influenced by configurations of stored sediment into channel and floodplain morphology that form a physical template upon which ecology develops. This topographic complexity in the riparian corridor is affected by hydrology, sediment transport, boundary conditions, and the history of channel change. This century has witnessed numerous examples of river adjustment and degradation of riparian habitats in response to anthropogenic perturbations. River adjustment to perturbations such as dams, levees, and mining have serious ecological implications in both aquatic and terrestrial environments. However, to our knowledge there have been no attempts at constructing a scientific model which accurately represents such adjustments over large river basins and over decadal time scales. Consequently, most assessments of adjustment in large river-floodplain complexes are made after the fact and involve anecdotal interpretations (e.g. *Schumm and Winkley*, 1994, "The Variability of Large Alluvial Rivers").

We propose to develop a model capable of predicting morphological adjustments in a large channel and floodplain environment resulting from the implementation of restoration scenarios. It would be applied by resource managers and engineers to better anticipate the morphological outcome of particular restoration strategies and thus, their effect on channel and floodplain habitats over basin and reach scales and over decades.

Restoration Research Context

Due to ecosystem degradation and flood catastrophes stemming from major river valley development, California is rethinking past development projects involving construction of river controls (e.g. levees, inter-basin water transfers) that were aimed at transforming natural wetlands into farmland. A new effort has been born with intent to restore valley floor environments for the purpose of enhancing water quality, protecting wildlife, and reducing flood damage: the CALFED Bay-Delta Program, overseen by the California state and Federal governments. Some Ecosystem Restoration Program (ERP) goals of CALFED include removal or setting back of channel constraints to create river meander corridors, manipulation of sediment supplies, and alteration of flow releases below dams to mimic natural flow regimes. However, without a comprehensive, quantitative, process-based study of sediment and hydraulic regimes and the channel and floodplain morphology within a large river valley, any restoration effort would at best address only a small part of the problem, and at worst cause further unanticipated degradation.

As CALFED embarks upon a program of significant riparian-zone management, it becomes important to understand the processes which govern channel and floodplain morphology. We would utilize this opportunity to investigate the following questions.

- How will restoration measures involving changes in flow modification, changes in sediment supply, and channel alteration affect channel and floodplain morphology on the reach scale?
- How will changes in local channel and floodplain morphology affect the sediment balance at the basin scale?

In order to validate our modeling capability we will also address the following historical question.

- What does empirical evidence tell us about changes in sediment and hydrologic flux regimes in the past, and what were the resulting morphological changes?

Methods of Riparian Channel-Floodplain Investigation

The physical processes acting to create the complex morphology of a large channel-floodplain environment promote biodiversity of species and habitats by controlling habitat patch size and distribution, ecotones, disturbance regimes, food sources, temperature, connectivity between channel and floodplain, habitat substrate type, water depth, current velocity, corridor width, and landform diversity. The morphology of such an environment is an extremely complex mosaic that has been the subject of many descriptive studies and modeling attempts in geomorphology and river engineering. Riffle-pool sequences and the wavelength of river meanders have been assessed based on statistical properties of data from a number of similar rivers [*Keller and Melhorn*, 1978; *Gregory et al.*, 1994]. Width, depth, and velocity have been predicted based on discharge using hydraulic geometry relationships [*Leopold et al.*, 1964]. To predict planform change, river migration rate has been assessed by making measurements on successive aerial photographs, or by monitoring bank erosion sites (see [*Lawler*, 1993] for a review of techniques). Overbank sedimentation rates on floodplains have been measured using dendrochronology [*Sigafoos*, 1964], sediment traps [*Walling and Bradley*, 1989], and fallout radionuclides [*Walling*, 1999]. Although such empirical work may provide characterization of channel and floodplain morphology at-a-place and over the time scale of observation, the results are not applicable to other environments, temporal and spatial scales. Mathematical modeling may be used to extend the applicability of empirical observations by distilling the complexity of the fluvial system into a few primary physical processes.

Mathematical modeling has been used to predict a number of particular physical processes in channels and on floodplains. Mathematical modeling has been used to predict a number of particular physical processes in channels and on floodplains. Bank erosion resulting from pore-pressure failure has been modeled based on bank material properties [*Darby and Thorne*, 1996; *Simon and Darby*, 1997; *Mosselman*, 1998], and long-term meander migration has been predicted based on channel curvature [*Ikeda et al.*, 1981; *Johannesson and Parker*, 1989; *Furbish*, 1991; *Howard*, 1992]. Modeling has also been used to predict overbank sedimentation by diffusion [*James*, 1985; *Pizzuto*, 1987], by one-dimensional floodplain growth resulting from uniform deposition by a random distribution of flood events [*Moody and Troutman*, 2000], by estimating mean overbank flow velocity [*Wyzga*, 1999], and by convective transport using finite element models on large, flat floodplains [*Gee et al.*, 1990] and small, topographically-complex floodplains [*Nicholas and Walling*, 1998].

Other models integrate a number of fluvial processes to predict river channel adjustment at particular cross-sections. Sediment routing models, as they are known, relate sediment transport at each computational node to the flow field and bed material present there [*ASCE*, 1998]. Sediment routing models typically involve equations describing: conservation of mass (water); conservation of mass (sediment); conservation of momentum (water); and sediment transport [*Dawdy and Vanoni*, 1986]. The simplest of these may be classified as simple erodible-bed models (e.g. HEC-6) that predict cross-sectional change (i.e. aggradation or degradation) through straight river reaches based on imbalances in the transport of a heterogeneous mixture of sediment, which is computed using one of a number of common sediment transport formulae (e.g. [*Ackers and White*, 1973; *Engelund and Fredsoe*, 1976; *Yang*, 1979; *Parker et al.*, 1982]). The most complex routing models, called erodible-boundary models, also have the capacity for channel widening (refer to [*ASCE*, 1998] for a review). The best of these models have the capacity to assess channel change under the influences of unsteady flow conditions, channel curvature, and transverse flow.

Mathematical models are only tools and their utility is limited by their method of employment for specific problems and the shortcomings germane to their development. For example, most of the aforementioned models are deterministic (i.e. they are capable of predicting only a single outcome based on a set of inputs). Empiricism suggests, however, that there may be a number of possible outcomes based on the same set of inputs [*Singer and Dunne*, In Preparation]. Thus, a deterministic modeling strategy may belie the complexity inherent in fluvial systems. When considering systems which contain variability fostered by the random nature of storm magnitude, frequency, and duration, a stochastic approach is advocated [*Hirschboeck*, 1988]. A stochastic model, in this case, hinges on the use of a set of random or chance variables to represent the uncertainty in storm patterns. This may be accomplished by treating the physical processes (e.g. modes of sediment transport) themselves as stochastic phenomena [*Malmon et al.*, In Preparation], or by creating a series of stochastic storm inputs for use in a deterministic model. The latter technique is fairly easily accomplished in cases where there exists a large input dataset. A hydrological data series for a given place, for example, can be manipulated to create a random distribution of flood events which represents the range of possible floods that could occur at that place. By driving a deterministic model with this random input for a large number of simulations, one could analyze the statistical properties of the model output to develop predictive capability within the context of the inherent system variability.

We propose to develop a predictive model of river channel and floodplain adjustment that will incorporate natural hydroclimatic variability on the spatial and temporal scales relevant to restoration. The model will be developed using data from the Sacramento River basin in California.

2. Proposed Scope of Work

Geographical Location

The Sacramento Valley has a Mediterranean climate with mostly dry summers and wet winters dominated by large cyclonic storms [*CDWR*, 1994]. The river drains the northern part of the Central Valley of California and has a total drainage area of 6.8 x 10^4 km^2 comprising over one half of the total drainage area into the San Francisco Bay system [*Porterfield*, 1980]. The Sacramento River flows on a subsiding alluvial base that it has deposited as the surrounding mountains have been uplifted [*Bryan*, 1923]. It flows south from its source in the Trinity Mountains below Mt. Eddy through the counties of Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Yolo, Sacramento, and Solano to its mouth, the confluence of the San Joaquin River at Suisun Bay. It drains the 96km wide x 418km long Sacramento Valley, a broad fertile alluvial lowland basin located between the Sierra Nevada and the Coast Range [*Harwood and Helley*, 1987]. The Sacramento River basin is the principal source of water and sediment discharged to the Sacramento/San Joaquin Bay-Delta [*Porterfield*, 1980]. The region is riddled with dams, levees, dikes, and gravel mining operations, which affect the geomorphic character of the river and its floodplain, consequently affecting fish and wildlife habitat, as well as the ability of the river system to attenuate flood events. This study is focused on the Sacramento River Ecological Management Zone [*ERP*, Vol. 2, p. 159 & Figure 8]. It is applicable to the mainstem Sacramento River and its contiguous floodplain south of Shasta Dam in the north to the city of Sacramento in the south (Figure 1). Please refer to USGS 1:500,000 State of California topographic map (North Half) for another map perspective. Channel and floodplain dynamics in the Sacramento's tributaries will be excluded from the study, though their inputs of water and sediment will be accounted for. The Bay-Delta itself will not be studied explicitly though determinations may be made regarding water and sediment delivery as a result of land-use changes stemming from CALFED policy initiatives.

Approach

We will be investigating the processes of morphological adjustment within the Sacramento River basin at various scales of interest. Our aim is to understand these processes on a temporal and spatial scale appropriate for designing restoration strategies (i.e. decades and river reaches, respectively), while maintaining fidelity to the processes of the basin-scale fluvial system. We will model the Sacramento River and its floodplain on the **basin scale** as a single unit constructed of interacting reaches in order to accurately represent the complex responses inherent in the fluvial system [*Schumm*, 1977]. At the basin scale, we will model the channel and floodplain of reaches (~60 km) to define which of them will be in aggradational, downcutting, or steady-state phases under different scenarios of flow and sediment management. As such, our model could be used to target restoration strategies for particular reaches. We will also conduct high-resolution modeling in target reaches to determine the decadal-scale response of specific **reach-scale** restoration measures. At the reach-scale, we will model the channel and floodplain morphology (over ~10 km reaches) to resolve incremental floodplain growth, changes in width, depth, and planform features including point bars. The overall model will probabilistically predict channel and floodplain morphology resulting from streamflow modification, changes in sediment supply, and channel alteration. Our research strategy comprises four parts: empirical characterization, channel modeling component development, floodplain modeling component development, and predictive modeling. Figure 2 shows the conceptual flow of this research, including model components, their output, analysis, and final products.

Empirical Characterization

In order to gain an understanding of the physical processes in action in a particular river system and to provide input data for physical modeling, it is necessary to analyze the empirical data that exist for that system and to collect data where significant voids exist. Initially, we will focus on field data collection and empirical characterization of the Sacramento basin. We are working to quantify empirical relationships between the regimes of water and sediment, morphological process, and resultant form of river channels and floodplains within the Sacramento basin. We have already evaluated the suspended sediment component of the mass

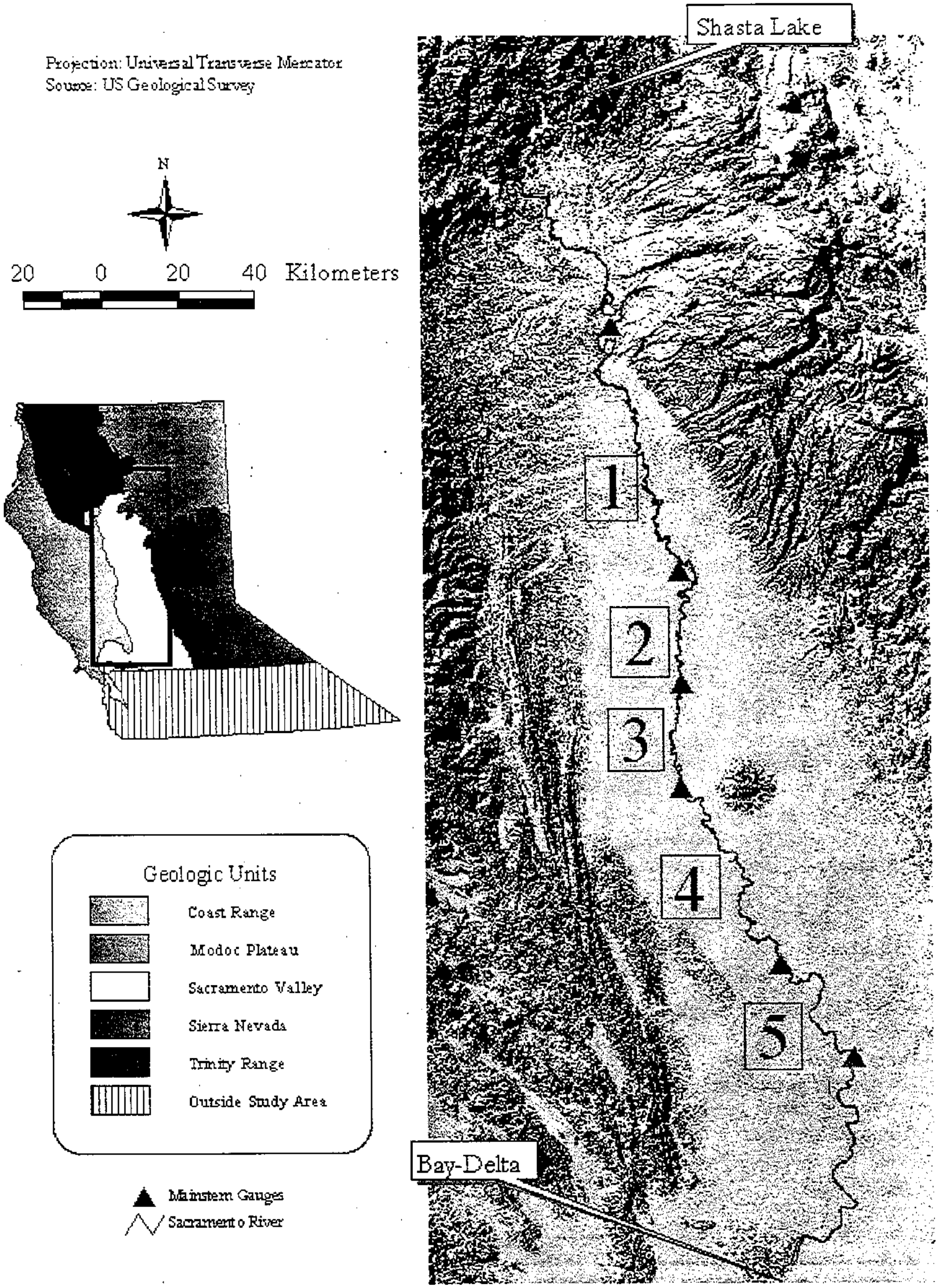

Figure 1. Map of study area depicting mainstem river reaches and geologic units from which tributaries rise. Section 1 includes reaches 1,2, and 3. Section 2 includes reaches 3 and 4.

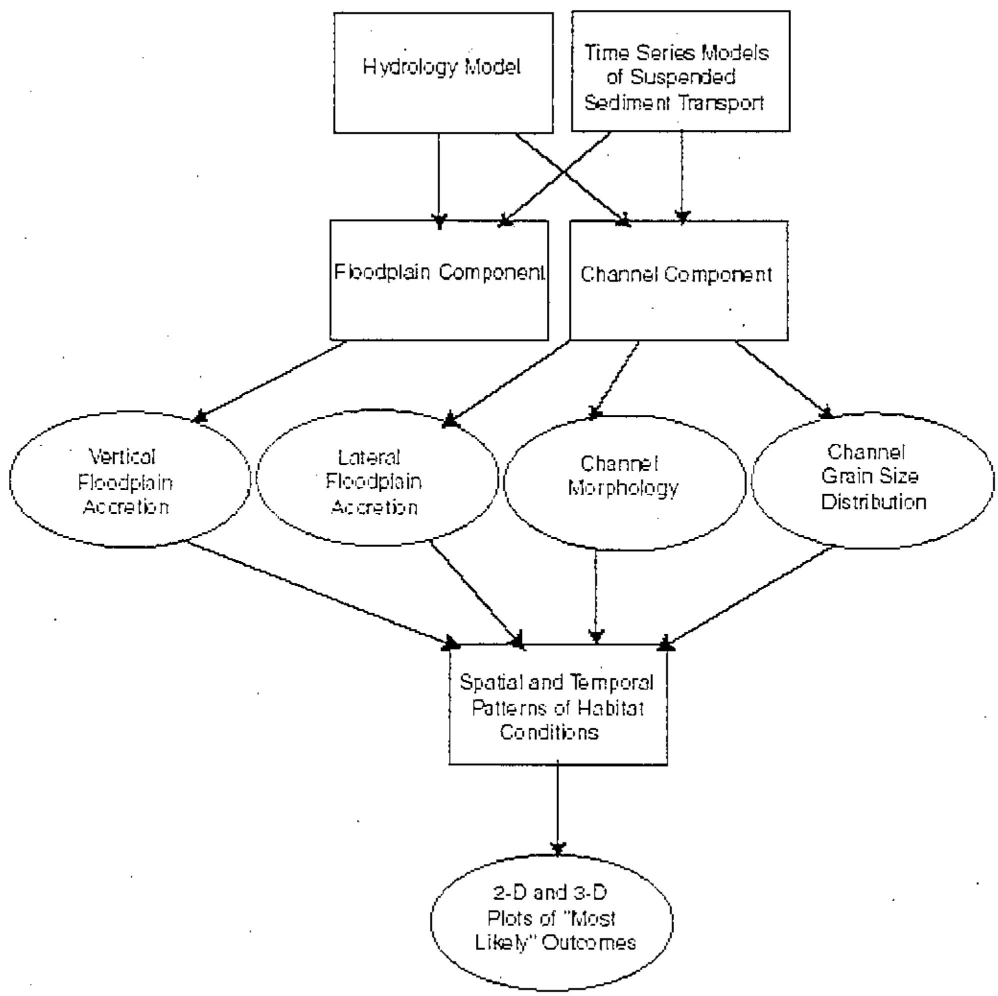

Figure 2. Conceptual flow model of overall research strategy.

balance on the Sacramento River [*Singer and Dunne*, In Preparation]. Next, we will assess the bedload transport and the grain size composition of bed and bank materials on the mainstem. The bedload flux will be assessed using measured bedload transport values (USGS) in conjunction with historical records describing the activities of in-channel gravel mining and sediment replenishment (gravel feeding). Since these data are limited, they will be used only to check the Channel Modeling Component (see below).

The grain size composition of the bed and banks will be determined by field survey. We will travel the length of the mainstem (from Sacramento to Keswick Dam) by boat and collect the grain-size information for each sediment storage reservoir (i.e. the bed and banks) on a reach-by-reach basis. Information on riverbed texture will be collected by grab sampler from a boat with positional information registered using the Global Positioning System (GPS). We will obtain grain-size distributions from these samples using standard laboratory sieving techniques. We will assess bank material erodibility, i.e. the level of bank protection, using digital photography registered with GPS at each bed texture sample location.

We will use an auger to collect floodplain cores at regularly spaced transects perpendicular to the river channel. They will be sieved and dated using ^{210}Pb according to a standard procedure [*El-Daoushy*, 1988] to construct a contoured surface of floodplain sedimentation rates. On the same field survey, we will document "hard points", or engineering structures that would impede erosion at channel cross-sections. Other modeling inputs, including slope and channel curvature, will be calculated from US Geological Survey 1:24,000 topographic maps. We have acquired high resolution DEMs (~2m) for the Sacramento River basin, that were developed for the California Department of Conservation (CalDOC) using InterFerometric Synthetic Aperture Radar (IFSAR). These maps will be used in conjunction with satellite imagery to develop a potential surface for overbank sedimentation (see Floodplain Modeling Component).

Channel Modeling Component

Next, we will focus on channel component development and calibration. Of the family of erodible-boundary channel models recently reviewed [*ASCE*, 1998], we have determined that FLUVIAL-12 [*Chang*, 1988] is applicable to large, lowland river systems (e.g. Sacramento River) because it accounts for unsteady flow conditions, channel curvature, and transverse flow, and includes the capacity for grain size sorting, as well as transport of both bedload and suspended load in gravel and sand size classes. FLUVIAL-12 calculates width adjustments by determining the change in cross-sectional area via sediment routing and applying this change to both the bed and banks to achieve uniformity of stream energy gradients. Material grain size distributions from 'eroded' banks are then transferred directly to the bed material active layer. In accounting for channel curvature, this model is capable of lateral floodplain accretion by constructing point bars (H. Chang, pers. comm.).

In the model development phase, FLUVIAL-12 will be driven by historical records of daily flow using older cross-sections, and calibrated using recently-collected morphological data. Refer to Figure 3 for the following discussion. We will select river cross-sections from previously published reports (e.g. Department of Water Resources from 1978) and match them with cross-sectional data extracted from new high resolution river profile data (3-D) collected by the Army Corps of Engineers in 1997 (in our possession). Inputs to the channel modeling component include roughness, hard points, bank erodibility, maximum scour depth, bed grain size distributions, volumes of gravel harvesting, volumes of dredging, and channel curvature will be derived from map analysis, acquisition of data records, and field survey (see Empirical Characterization). We will utilize historical records for one mainstem (Bend Bridge) and eighteen tributary gauging stations (corresponding to major tributaries in the manuscript by Singer and Dunne, In Preparation) to route flood waters in the mainstem Sacramento. We will route water and sediment through the original cross-sections according to the historical daily flows that existed at these stations between 1978 and 1997. We will likely need to do some calibration by adjusting FLUVIAL-12's free parameters (i.e. maximum scour depth, bank erodibility) to derive a more accurate model for prediction.

The Sacramento River will be divided into two sections for which the materials and physical processes are distinct. Section 1 encompasses the area between Shasta Dam and Colusa (i.e. Reaches 1,2, and 3 in Figure 1) and Section 2 from Colusa to Sacramento (i.e. Reaches 4 and 5 in Figure 1). FLUVIAL-12 will be run in Section 1 using the Engelund-Hansen [*Vanoni*, 1975] sediment transport formula for total load. In Section 2

FLUVIAL-12 will be run using the Yang formula for sand transport [*Yang*, 1973]. These sediment transport formulae have been selected based on their success in modeling similar physiographic environments [*Reid and Dunne*, 1996]. Sediment transport calculations will be made using unsteady daily flow conditions on the mainstem. We will use the corresponding flow records from major tributary stations near the confluence with the Sacramento to account for tributary inflow. Washload influx from these tributaries will be calculated separately using Box-Jenkins time series models [in MATLAB] that relate sediment concentration to discharge by accounting for system memory (refer to Singer and Dunne, In Preparation).

Floodplain Modeling Component

In a later stage, if time and resources permit, we will develop the floodplain component model, which will be used to predict floodplain accretion due to inundation and overbank sedimentation, based on our previous empirical work. The processes of overbank flooding and deposition have important ecological implications related to flooding frequency and depth, transfer of dissolved and particulate nutrients (and possibly toxins) overbank, and the filling of small water bodies and channels on the floodplain [*Petts et al.*, 1992]. Please refer to Figure 4 for the following discussion. We will use the high resolution DEM maps (from CalDOC) and satellite imagery (from NASA) to develop a depositional floodplain surface which excludes regions of high topography (above a regionally-assigned elevation threshold that corresponds to the high flow level). The lateral extent of this surface (transverse from the channel) will be defined by the remotely-sensed spectral signature of the interaction zone between perirheic water and river water from Landsat scenes taken during large flood events (e.g. 1997). It has been found that perirheic water impedes the transport of sediment beyond this interaction zone [*Mertes*, 1997].

Once the depositional surface is defined, we will use stage output from FLUVIAL-12 for specific reaches to map inundation patterns over the DEM floodplain surface. Next on a reach-by-reach basis, we will relate hydrographs that are output from FLUVIAL-12 at mainstem gauging sites to Box-Jenkins models, to determine the mean sediment concentration for the volume of water that leaves the channel and enters the floodplain. We will assume the concentration is of a single grain size (very fine sand). The sediment in suspension on the floodplain will be deposited by multiplying the concentration by the volume of water above the land surface and dividing by the bulk density of the sediment. Initially we will assume 100% trap efficiency on the floodplain. We will create a surface of deposition over the DEM by running the model over a period of decades. Then we will calculate sedimentation rates from floodplain transect cores using ^{210}Pb and define surface contours of sedimentation rates (mm/yr) over the DEM for the entire reach. We will then compare the observed sedimentation surface with the predicted one. If the surfaces do not match, we will adjust the trap efficiency for each surface contour by relating long-term sedimentation rate to mass of sediment deposited in the long-term simulation. Finally, we will calculate flood-based floodplain growth using the flood stage series output from FLUVIAL-12 and the morphological data describing the channel boundaries. The floodplain component may be refined in the future with the creation of high spatial and temporal resolution flood maps that would enable prediction of vertical accretion based on hydraulics rather than an empirical procedure. In the meantime, however, this technique will test the hypothesis that the "ponding" approximation described above will represent the incremental growth of floodplains due to flood events. To reflect the influence of restoration scenarios on this component, we will alter the width of the depositional floodplain depositional surface according to channel and levee alteration.

Predictive Modeling

Finally, we will use the model to answer the research questions. We will make predictions of channel and floodplain adjustment to human modifications by employing our model using stochastic hydrology. As such our process model will account for the stochastic nature of floods and thus, represent the variability of sediment transport processes in the fluvial system. For this purpose, we will develop a separate **hydrology model** that will be used to drive both channel and floodplain model components. The same gauging stations used in model development will be used for predictive modeling. Refer to Figure 5 for the following discussion. The hydrology model initialization begins by dividing flood records for all stations into Pre-Dam

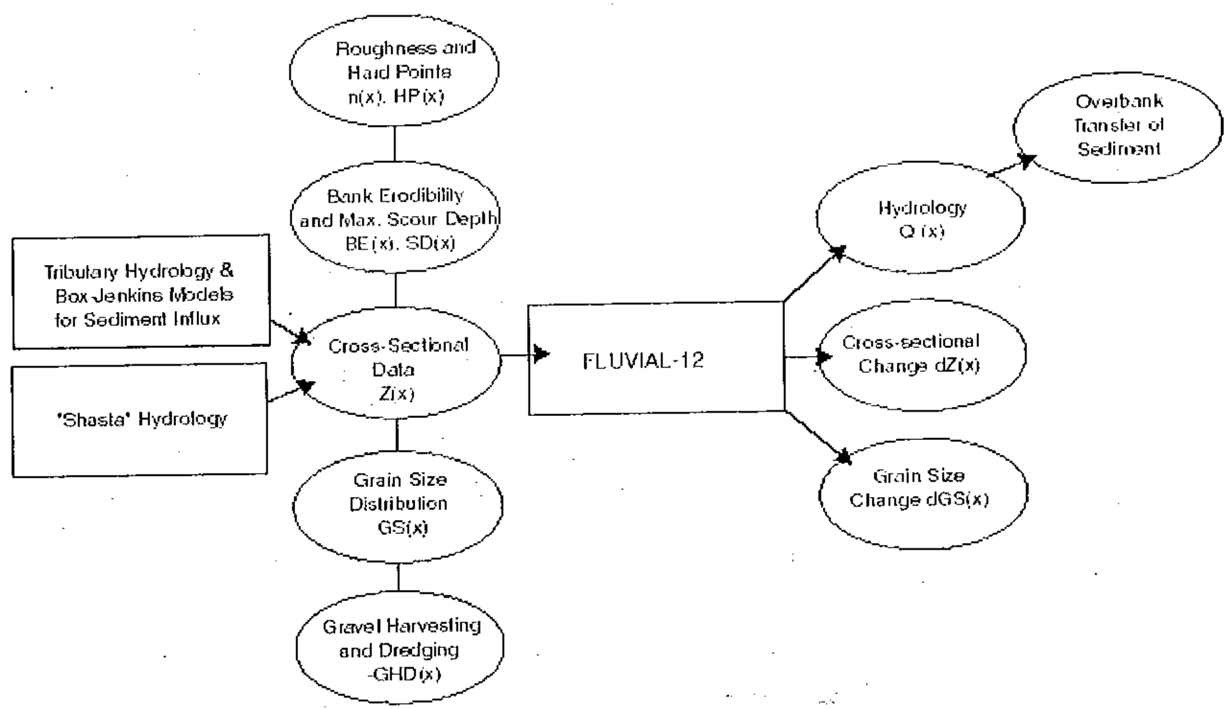

Figure 3. Conceptual flow of channel component.

Floodplain Sedimentation Model

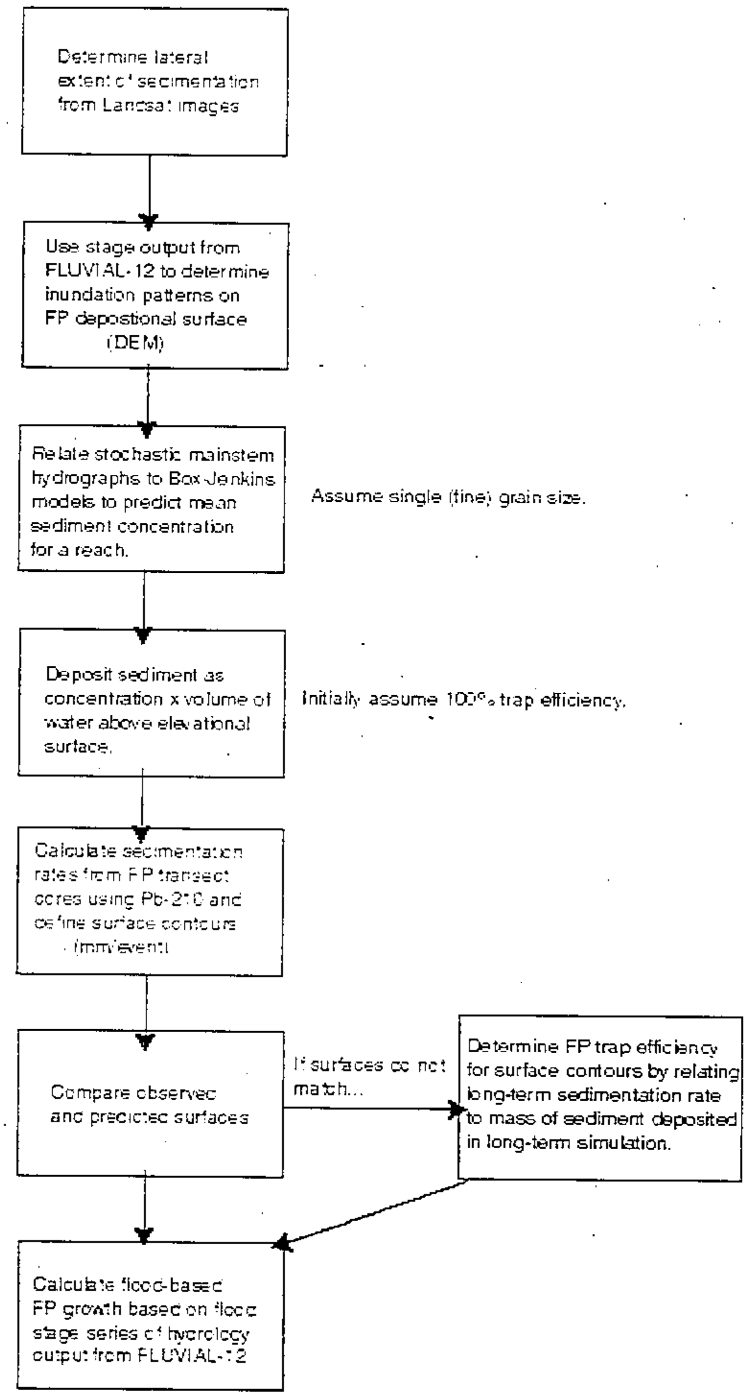

Figure 4. Conceptual flow diagram of floodplain component.

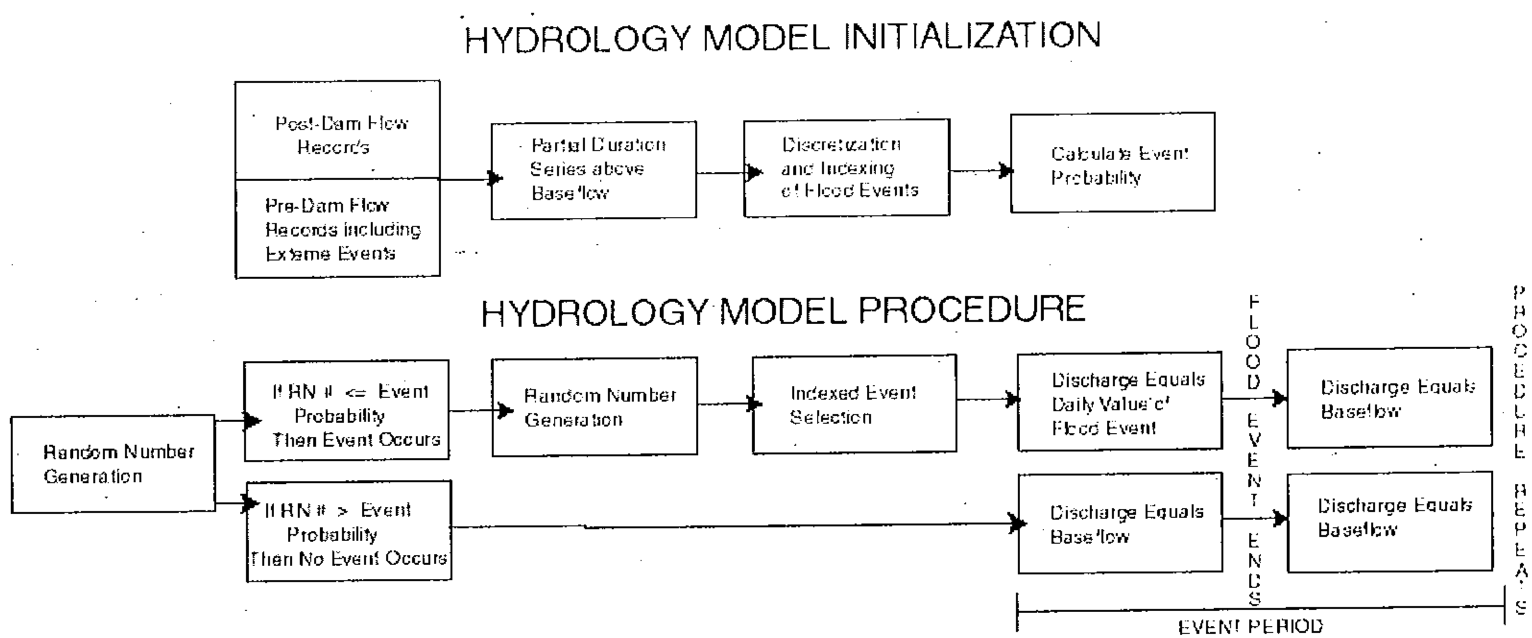

Figure 5. Flow diagram of initialization and operation of stochastic hydrology model.

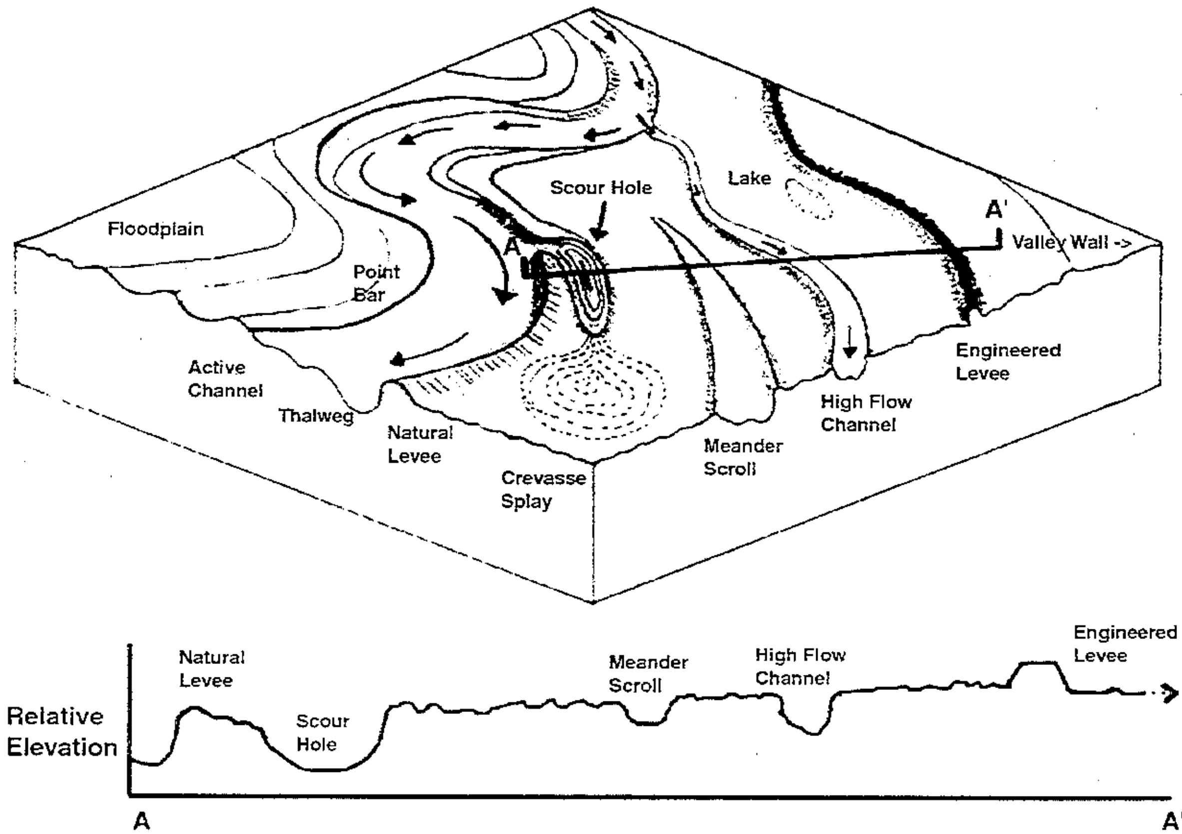

Figure 6. Schematic showing perspective of "most likely" outcome snapshots that will be generated. A snapshot's idealized view will be enhanced with a DEM to represent channel width and depth, point bars, levees, and floodplain growth associated with different floodplain features. "Most likely" outcome snapshots will be compared with pre-restoration snapshots.

and Post-Dam series, to account for the influence of Shasta Dam on the flow regime. We will divide the historical flood record at each station into a winter season (October 1-May 31) and a summer season (June 1-September 30) to represent persistence of storms periods and dry periods, respectively. Within each season we will then define the probability of having a flood event at each gaging station by dividing the number of flood days in the partial duration flood series (above a predetermined baseline flow) by the number of total days in the flow record. This will account for the spatial variability of storm tracks and for sequences of storms or dry weather. Then we will discretize continuous sequences of discharge days in the partial duration series into indexed flood events that vary in magnitude and duration. These floods will be stored separately where they can be called according to their index numbers. The collection of floods in the Pre-Dam series will be augmented at each station by synthetic hydrographs developed for extreme floods, similar to the one that occurred in the Sacramento basin in 1862 [*Engstrom*, 1996].

The hydrological modeling procedure begins by generating a random number for an event period and comparing it to the event probability at each station. If the event probability for a station is less than the random number, then no event will occur at that station and its discharge value for that event period will be equal to the baseflow discharge. If the event probability is greater than or equal to the random number, an event will occur by generating another random number. This random number will be related to the indexed flood events for that station, and the closest indexed event will be chosen. This actual historical flood will be run for its entire duration (in days). In this stochastic approach, there may be multiple events of different durations occurring at different stations simultaneously. The length of an event period corresponds to the duration for the longest event of that period. Therefore, when an event for a station terminates before the end of the event period (i.e. its duration is shorter than that of the event period), we will reset its discharge to the baseline flow for that station until the end of the event period (i.e. until the longest flood event in the basin is complete). At the completion of the event period, we will generate a new random number to compare with event probabilities and the cycle will repeat.

We will use this hydrology model to drive the channel component (FLUVIAL-12) with stochastic flow events in order to predict cross-sectional changes in channel morphology on the Sacramento River. Again suspended sediment supply at each junction will be drawn from Box-Jenkins models. In this phase, we will quantify the transfer of suspended sediment overbank by coupling FLUVIAL-12's output hydrographs on the mainstem to Box-Jenkins models, but will not represent the resulting morphological adjustment of the floodplain.

In predictive mode, we will adjust model inputs and boundary conditions to reflect implementation of restoration strategies (i.e. changes in flow, sediment supply, and channel alteration). To simulate the effects of altering the flow regime through alternative dam operation, flood flow will be uniformly increased in the winter season and baseflow will be decreased in the summer season. To simulate feeding of spawning gravels, bed sediment will be fed within the channel component by specifying the location and grain size distribution of the added sediment. To simulate the effects of setting back levees to promote meander corridors, the channel will be altered by adjusting cross-sectional width and bank heights at specified points. When we theoretically remove project levees, we will also retain a low natural levee surface on the channel banks. By utilizing the historical hydrologic flow record for the Sacramento basin in a stochastic simulation we ensure that unsteady flow conditions are met, and that modeling results will yield resultant morphology in the form of probability distributions of channel dimensions and floodplain features, which account for the inherent variability in a river system.

Data Handling and Review

All hydrological and sediment data will be stored in a series of MS Excel spreadsheets, will be processed in MATLAB, and will be available for download in tab delimited text format on an Internet website. Digital Elevation Data, satellite imagery, and aerial photographs are publicly available from the Earth Resources Observation Systems (EROS) Data Center. High-resolution channel data are available from the US Army Corps of Engineers. Some of these data will also be available for download via FTP on our website upon request. Models used in this research (other than the proprietary FLUVIAL-12) will also be made available to the public upon request.

We will utilize the services of a consulting firm for advice in model development and to review the scientific products of this research.

Expected Output

By driving both model components with multiple flood events over a period of decades, we will generate "most likely" scenarios of resultant channel and floodplain morphology at the reach- and basin-scales. The morphological output from the channel component will be in the form of channel cross sections and grain size distributions (Figure 4). We will generate statistics on the output that describe the probability of the system being a particular state. For example, the model might predict that setting back levees in a particular reach will have a 60% chance of increasing channel migration over 3 m/yr and a 30% chance of building a bar over 2 m in that reach. Specific output files from FLUVIAL-12 that correspond to "most likely" outcomes will be processed using a PERL script and imported into MATLAB for plotting.

On the **basin scale**, we will describe major imbalances in the sediment budget in response to restoration scenarios. We will identify reaches (~60 km) of net deposition and erosion that could serve to undermine restoration efforts. We will analyze the spatial and temporal patterns in the mass balance over a period of decades. "Most likely" outcomes will be plotted on graphs of net sediment divergence against downstream distance. We will also plot temporal changes in sediment flux at specific points along the mainstem.

On the **reach scale**, we will develop a program that interpolates between cross-sections and plots a reach (~10 km) of channel. We will resolve changes in morphological features including point bars, floodplain channels, mid-channel islands, channel width and depth, and levees. The grain size information will be added to these plots as a color ramp, representing percentile of grain size. Output from the floodplain component will describe (in DEM format) long-term floodplain accretion over a contoured depositional surface. We will connect "most likely" outcome plots from the channel component with those from the floodplain component to create a reach-scale planform or 3-D pseudo-planform (slightly tilted to show elevation differences) snapshots of the channel-floodplain complex in response to restoration scenarios. These snapshot plots will highlight two-dimensional sediment accumulation in reaches and adjustment in bed texture. Juxtaposing these "most likely" outcome snapshots for a particular reach of river with similar plots describing pre-restoration conditions, will provide concrete visualized understanding of the likely consequences associated with a particular restoration action. Figure 6 is a schematic of the perspective of a reach-scale snapshot.

This comprehensive modeling strategy and analysis would allow habitat restoration scenarios to proceed in the context of their long-term consequences on the basin-scale sediment budget and on reach-scale morphology, in light of stochastic flow and sediment transport in the fluvial system.

Work Schedule

Year 1: Data collection, field campaign, channel component development. Presentation at American Geophysical Union Fall Meeting, CALFED symposia, and other relevant conferences. Write paper for professional scientific journal on field-tested channel component model employment.

Year 2: Predictive channel modeling. Presentation at American Geophysical Union Fall Meeting, CALFED symposia, and other relevant conferences. Write papers for professional scientific journals on hydrology model and predictive channel component modeling results.

Year 3: Continue predictive channel modeling. Time permitting, floodplain component development and predictive floodplain modeling. Presentation at American Geophysical Union Fall Meeting, CALFED symposia, and other relevant conferences. Write paper for professional scientific journal on channel-floodplain modeling results.

Summary

The purpose of this modeling effort is to provide a physically sound explanation of empirical measurements and to generalize from the recorded data to a broader range of environmental scenarios. A mathematical model would allow us to consider for example, the probable effect of alterations of flow regime, changes in sediment supply, or channel modification on sediment transport processes within particular reaches and within the basin as a whole. This research will result in predictions of the effects these restoration strategies would have on morphological indicators and thus, indirectly upon target species within the Sacramento River basin. It will allow policymakers to anticipate resultant morphological conditions relevant to habitat restoration and flood control strategies such as restoration of "natural" valley streamflow regimes, gravel feeding below dams, or setback levees [*ERP*, Vol.1, p.42-43].

Employing this multi-scale, integrated modeling approach will provide understanding of the process of river adjustment in the context of valley-floor evolution at the basin-scale and of morphological change pertaining to habitat considerations on the reach-scale. The model will yield a picture of morphological channel-floodplain adjustment to regime variability and perturbations over a period of decades. By addressing the problems of the Sacramento Bay-Delta with an integrated, comprehensive approach of this kind the CALFED Bay-Delta Program could set the international standard for restoration of large lowland river systems.

D. APPLICABILITY TO CALFED

Ecological Implications

In the last 150 years since the discovery of gold in the Sierra Nevada, the Sacramento River valley has been drastically transformed by agriculture and human settlement, and thus, by radical flood control policies intended to ensure the survival of these floodplain activities. After decades of trial-and-error flood-control policy on the part of the state and valley residents, the federal government finally committed itself to a unified basin-scale flood control policy. The policy (still in effect) was based on conveying water and sediment as efficiently as possible through the mainstem Sacramento River, using straightened channels and high levees built upon protected river banks to prevent overbank flooding and bank erosion and therefore, lateral channel migration. To relieve pressure on the channel banks and mitigate flood hazard potential, water is impounded behind dams and pumped into flood bypass channels constructed in existing lowland flood basins.

Although flood hazards and flood damage may have been reduced as a result of damming, channelization, and bank protection on the Sacramento River, the increased flood control has come at the expense of natural bar and riffle formation, thus disrupting a crucial component of riverine ecosystem habitat [*ERP*, Vol.1, p. 29-30]. The Sacramento River provides important spawning, rearing, and migratory habitat to anadromous fish populations including chinook salmon (fall and spring runs), splittail, steelhead, white sturgeon, green sturgeon, striped bass, and American shad [*ERP*, Vol.2, p. 165]. The reduction of bars, riffles, and other morphological features within the river channel has hampered salmon spawning runs and movement of other species by reducing resting habitat for fish on their upstream journey. The in-channel ecosystem has been further disrupted by the elimination of upstream and bank erosion sediment sources, thereby preventing replenishment of gravels vital for spawning [*Reeves and Roelofs*, 1982; *CDWR*, 1985]. Additionally impoundments dampen flood peaks preventing flushing flows necessary for removing fine accumulations of sediment from spawning gravels [*Milhous*, 1998]. Channelization has also resulted in the loss of side channel habitat required by more sedentary species and wintering salmon (as well as a loss of terrestrial riparian vegetation and the species it supports) because it prevents overbank flooding. The Central Valley Project Improvement Act (CVPIA) and its Anadramous Fish Restoration Program (ARFP) call for restoring fish habitats and eliminating stressors by implementing strategies including alteration of flow and sediment supplies, and physical modification of river channels [*Kondolf et al.*, 1996]. Furthermore, one of the fundamental Strategic Ecosystem Goals of CALFED is to rehabilitate natural process in the Bay-Delta system [*ERP*, Vol. 1, p.1]. Such a restorative effort requires a system-wide view of the river's channel and floodplain morphology and the processes involved in shaping it over a time scale of decades.

System-Wide View

The morphology of a river is determined by the interaction of water and sediment within a channel network. A river flows in an intricate path, entraining and transporting a supply of water and sediment, augmented by tributaries. The river deposits and re-mobilizes the sediment along its valley floor. Where the river lies entirely within its own mobile alluvium, it is classified as an alluvial river, and often obeys certain regularities of form and behavior that allow prediction [*Leopold et al.*, 1964; *Schumm*, 1977]. Fluvial landforms contain information on the depositional and erosional activities of the river, as it continually adjusts to the variable amounts of water and sediment that enter its channel network. It is the spatial and temporal variability of these landforms through the fluvial system which determines the potential flood conveyance capacity, stability of natural and engineered river courses, and the complexity of river channel and riparian habitat [*Dunne*, 1988; *Kondolf and Wolman*, 1993; *Kondolf*, 1995a; *Kondolf*, 1995b]. In the context of CALFED, these landforms are indicators of riverine habitat as the fluvial system adjusts to restoration strategies involving major system alterations [*ERP*, Vol. 1, p. 6].

The fluvial system can be divided into three distinct zones: the production zone, the transport zone, and the deposition zone [*Schumm*, 1977], each of which functions differently in terms of its net transport of materials and thus, its erosional and depositional processes. All zones in the fluvial system are linked. That is, deposition or erosion in one reach of a fluvial zone will affect transport in adjacent zones both upstream and downstream. These adjacent reaches will in turn, affect material transport in their adjacent reaches, and even far downstream. It is apparent that research on material transport processes on the scale of one particular reach cannot represent the fluvial system as a whole, because it does not evaluate feedbacks in material transport between river reaches, including effects far downstream. This spatial variability of transport must be considered along with the temporal variability associated with storm patterns and floodplain storage and remobilization [*Dietrich*, 1982; *Dunne et al.*, 1998]. Restoration strategies must be designed to cope with the dynamic nature of hydrologic and geomorphic processes [*ERP*, Vol.1, p.5]. A basin-scale model of spatial and temporal regime variability will foster a process-based understanding and predictive capability transport processes and resultant morphology within the fluvial system.

Adjustment to Controls

Throughout the fluvial system there are constraints, or controls, on material transport, which result in some level of morphologic adjustment on the part of the river system. Such controls, or perturbations, are either natural (e.g. tectonic, climatic) or anthropogenic (e.g. dams, levees, channel re-alignment, gravel mining). As new perturbations are imposed, adjustments are made by the fluvial system, which can radically change a river's planform and cross-section. However, there has been no research effort at creating a reach-integrated, basin-wide view of morphologic adjustment. Such a broader perspective could facilitate the planning of restoration efforts in river systems in the context of widely acknowledged, but rarely quantified, basin-scale cumulative effects.

Flood control planning and ecosystem rehabilitation both need to be based on understanding of the history of river channel change and therefore of materials flux regimes [*ERP*, Vol. 1, p. 79]. It is well known that river channel change results from a set of erosional and depositional processes by which a river adjusts to perturbations. For example, when dams are installed, a river system goes through a complex process of adjustment [*Schumm*, 1981; *Williams and Wolman*, 1984; *Xu*, 1990] to changes in supply of water and sediment. Morphological adjustments to reservoirs are typified by backwater effects and sediment deposition upstream of the dam and by scour of bed material downstream [*Chien*, 1985]. Mining within river basins also contributes to complex responses in river systems. This can occur as a result of valley-floor mining, wherein the system must adjust to a decrease in riverbed or floodplain sediment. Valley floor mining can cause bed elevations and width-depth ratios to decrease [*Collins and Dunne*, 1989; *Collins and Dunne*, 1990], and can cause channel migration as flow is deflected from in-stream gravel pits [*Dunne and Leopold*, 1978]. Channelization, or channel dredging and straightening for navigation or flood control, has effects similar to those of intra-valley floor mining with the added tendency for acceleration of bank erosion and meandering [*Neill and Yaremko*, 1988] and piping of levees and dikes [*Olson et al.*, 1942; *Feldman*, 1973; *Laddish*, 1997; *Schalk and Jacobson*, 1997].

In all these cases morphological adjustments have been described by their resultant form characteristics of cross-sectional channel geometry [*Gregory and Park*, 1974; *Xu*, 1996], bed material sizes [*Williams and Wolman*, 1984], and longitudinal profile [*Chien*, 1985]. However, in the context of complex river response to perturbations [*ERP*, Vol.1, p. 13-14], attempts to explain the physical processes associated with adjustments have relied upon qualitative assessments [*Xu*, 1990], thus preventing their accurate application in other localities with different spatial and temporal scales of material flux and levels of disturbance. To provide a foundation for riverine ecosystem rehabilitation, we will construct a process model of basin- and reach-scale channel and floodplain morphological adjustment that is based on an excellent historical empirical dataset collected within the Sacramento River basin.

E. QUALIFICATIONS

Michael Singer is a Ph.D. student in the Donald Bren School of Environmental Science and Management. The bulk of the research proposed herein comprises his dissertation work.

His research experience stems from his undergraduate work at The Evergreen State College where he surveyed urban watersheds in Olympia, Washington and investigated tree canopy microclimate in Monteverde, Costa Rica. Following graduation, he prepared samples for Argon-Argon dating of soil and rock samples at the Berkeley Geochronology Center. He spent two years in the US Peace Corps mapping landslides, training forest rangers in survey and mapping techniques, and implementing vegetative geotextiles to stabilize road slopes in Nepal. He arrived in Santa Barbara in 1996, where he worked preparing geochronology samples for apatite fission track analysis to determine river incision rates in the Andes Mountains. Subsequently, he worked on a review, for the Environmental Defense Fund, of the proposed Hidrovia channelization project on the Paraguay-Parana River system draining the Pantanal of South America. His experience with river modeling has developed with his application of the erodible-boundary model, FLUVIAL-12, to assess sediment transport and channel adjustment in the ephemeral stream in Pueblo Canyon, below Los Alamos National Laboratory.
He has completed a study relating flow to suspended sediment transport on the Sacramento River over a period of decades and related this to spatial patterns of sediment storage. These results of this research with Thomas Dunne, entitled "Long-term analysis of suspended sediment transport in the Sacramento River, California", are being prepared for submission to the scientific journal Water Resources Research, and were presented in 1999 at the International Conference on Drainage Basin Dynamics and Morphology in Jerusalem, Israel.

In 1999, Michael traveled to the Danube Delta Biosphere Reserve, a large restoration project in Romania, to observe and collect information on the effects of large-scale restoration works (e.g. breaching dikes) on the physical processes of hydrology and sediment transport. He has traveled extensively and has gleaned familiarity with a wide array of river environments.
In 1999-2000, Michael served on the Scientific Review Panel for the CALFED white paper entitled "Flow Regime Requirements for Habitat Restoration along the Sacramento River between Colusa and Red Bluff".

F. COST

The project budget is provided in Table 1.

G. LOCAL INVOLVEMENT

The proposed work is a research project and will affect local groups and organizations in so far as the results are utilized by CALFED to target and scope restoration works. We have been in active communication with officials from the Nature Conservancy and plan to develop research collaborations with them in the future. Additionally, we will present our findings to local government agencies, groups, and land owners upon request.

We have already been communicating with other researchers who are studying physical processes on the Sacramento River. These researchers include Eric Larsen (UC Davis) who is studying meander migration in particular reaches of the Upper Sacramento River and Randall Dinehart and Dave Shellhammer (USGS), who have been investigating bedform dynamics in the Lower Sacramento (below the City of Sacramento).

H. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

The applicant has reviewed and is able to comply with the terms and conditions set forth in Appendix D and E of the Proposal Solicitation Package. Additional forms required for submittal are provided in Appendix 2.

I. LITERATURE CITED

The Literature cited in this document can be found in Appendix 1.

J. THRESHHOLD REQUIREMENTS

The following threshold requirements can be found in Appendix 2:

- Letters of Notification
- Environmental Compliance Checklist
- Land Use Checklist
- Federal and State Contract Forms

Table 1.

Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

Year	Task	Direct Labor Hours	Salary	Benefits	Travel	Supplies	Service Contract	Overhead (8%)	Total Cost
Year 1	1. Empirical Characterization	2,080	38,480	3,848	13,100	27,150	4,820	6,992	94,390
	2. Channel Modeling Component	2,080	38,480	3,848			4,820	3,772	50,920
	3. Floodplain Modeling Component							-	-
	4. Predictive Modeling							-	-
Year 1 Total Cost		**4,160**	**76,960**	**7,696**	**13,100**	**27,150**	**9,640**	**10,764**	**145,310**
Year 2	1. Empirical Characterization			-				-	-
	2. Channel Modeling Component			-				-	-
	3. Floodplain Modeling Component			-				-	-
	4. Predictive Modeling	4,160	80,808	8,081	13,755	7,315	10,120	9,606	129,685
Year 2 Total Cost		**4,160**	**80,808**	**8,081**	**13,755**	**7,315**	**10,120**	**9,606**	**129,685**
Year 3	1. Empirical Characterization			-				-	-
	2. Channel Modeling Component			-				-	-
	3. Floodplain Modeling Component	4,160	84,656	8,466	10,584	1,381	10,640	9,258	124,985
	4. Predictive Modeling							-	-
Year 3 Total Cost		**4,160**	**84,656**	**8,466**	**10,584**	**1,381**	**10,640**	**9,258**	**124,985**
Project Total Cost		**12,480**	**242,424**	**24,242**	**37,439**	**35,846**	**30,400**	**29,628**	**399,980**

APPENDIX 1

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Appendix 2

May 12, 2000

Yolo County Planning Department
625 Court Street
Woodland, CA 95695

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Tehama County Planning Department
332 Pine Street -P.O. Box 250
Red Bluff, CA 96080

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Sutter County Planning Department
1160 Civic Center Blvd.
Yuba City, CA 95993

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Shasta County Planning Department
1815 Yuba Street, Suite 1
Redding, CA 96001

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Sacramento County Planning Department
700 H Street
Sacramento, CA 95814

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Glenn County Planning Department
526 West Sycamore Street
Willows, CA 95988

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Colusa County Planning Department
546 Jay Street
Colusa, CA 95932

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

I am writing to inform you that I am submitting a research proposal to the CALFED Bay-Delta Program's Ecosystem Restoration Program, and that the results may have implications for your county. I am proposing to model the effects of a few ecosystem restoration scenarios on the evolution of river channel and floodplain environments along the Sacramento River. The research involves assimilating a number of historical datasets that have been collected over the last century, and using them to construct a predictive mathematical model.

I will be sending you a copy of the proposal for your records and review.

Sincerely,

Michael Singer

May 12, 2000

Butte County Planning Department
25 County Center Drive
Oroville, CA 95965

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Michael Singer

May 12, 2000

Yolo County Clerk of Board of County Supervisors
625 Court Street
Woodland, CA 95695

Michael Singer
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4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Sincerely,

Michael Singer

May 12, 2000

Tehama County Clerk of Board of County Supervisors
332 Pine Street -P.O. Box 250
Red Bluff, CA 96080

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Sincerely,

Michael Singer

May 12, 2000

Sutter County Clerk of Board of County Supervisors
1160 Civic Center Blvd.
Yuba City, CA 95993

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Sincerely,

Michael Singer

May 12, 2000

Shasta County Clerk of Board of County Supervisors
1815 Yuba Street, Suite 1
Redding, CA 96001

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Sincerely,

Michael Singer

May 12, 2000

Sacramento County Clerk of Board of County Supervisors
700 H Street
Sacramento, CA 95814

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

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Sincerely,

Michael Singer

May 12, 2000

Glenn County Clerk of Board of County Supervisors
526 West Sycamore Street
Willows, CA 95988

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

To Whom It May Concern:

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Michael Singer

May 12, 2000

Colusa County Clerk of Board of County Supervisors
546 Jay Street
Colusa, CA 95932

Michael Singer
Donald Bren School of Environmental Science and Management
4670 Physical Sciences North
University of California
Santa Barbara, CA 93106

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Santa Barbara, CA 93106

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Michael Singer

Environmental Compliance Checklist

1. **Do any of the actions included in the proposal require compliance with either the California Environmental Quality Act (CEQA), the National Environmental Policy Act (NEPA), or both?**

   ___ **Yes**   X **No**

2. **If you answered yes to #1, identify the lead governmental agency for CEQA/NEPA compliance.**

   N/A

   Lead Agency

3. **If you answered no to #1, explain why CEQA/NEPA compliance is not required for the actions in the proposals.**

   The proposed project is a modeling project and thus will not impact any cultural or biological resources.

4. **If NEPA/CEQA compliance is required, describe how the project will comply with either or both of these laws. Describe where the project is in the compliance process and the expected date of completion.**

   Does not apply to proposed project.

5. **Will the applicant require access across public or private property that the applicant does not Own to accomplish the activities in the proposal?**

   X **Yes**   ___ **No**

   Permission for access agreements for sampling locations will be procured after specific sites are identified.

6. **Please indicate what permits or other approvals may be required for the activities contained in your proposal. Check all boxes that apply.**

   LOCAL

Conditional use permit	___
Variance	___
Subdivision Map Act Approval	___
Grading permit	___
General plan amendment	___
Specific plan approval	___
Rezone	___
Williamson Act Contract cancellation	___
Other___________ (please specify)	___
None required	X

<u>STATE</u>	
CESA Compliance	**___ (DFG)**
Streambed Alteration Permit	**___ (DFG)**
CWA &401 certification	**___ (RWQCB)**
Coastal development permit	**___ (Coastal Commission/BCDC**
Reclamation Board Approval	**___**
Notification	**___ (DPC, BCDC)**
Other ___________________ **(please specify)**	**___**
None required	**X**

<u>FEDERAL</u>	
ESA Consultation	**___ (USFWS)**
Rivers and Harbors Act permit	**___ (ACOE)**
CWA & 404 permit	**___ (ACOE)**
Other ___________________ **(please specify)**	**___**
None required	**X**

Land Use Checklist

1. **Do the actions in the proposal involve physical changes to the land (i.e. grading, planting vegetation, or breeching levees) or restrictions in land use (i.e. conservation easements or placing of land in a wildlife refuge)?**

   ____ **Yes**   X__ **No**

2. **If NO to #1, explain what types of actions are involved in the proposal (i.e. research or planning)**
   Proposed project is research/modeling only.

3. **If yes to 1, what is the proposed land use change or restriction under the proposal?**
   Not applicable to proposed project.

4. **If YES to #1, is the land currently under a Williamson Act contract**
   Not applicable to proposed project.

5. **If YES to #1, answer the following:**
   Current land use Not applicable to proposed project.
   Current Zoning Not applicable to proposed project.
   Current general plan designation Not applicable to proposed project.

6. **If YES to #1, is the land classified as Prime Farmland, Farmland of Statewide Importance or Unique Farmland on the Department of Conservation Important Farmland Maps?**
   Not applicable to proposed project.

7. **If YES to 1, how many acres of land will be subject to physical change or land use restrictions under the proposal?**
   Not applicable to proposed project.

8. **If YES to #1 is the property currently being commercially farmed or grazed?**
   Not applicable to proposed project.

9. **If YES to #8, what are** **the number of employees/acre** Not applicable
   the total number of employees Not applicable

10. **Will the applicant acquire any interest in land under the proposal (fee title or a conservation easement)?**

    ____ **Yes**   X____ **No**

11. **What entity/organization will hold the interest?** Not applicable to proposed project.

12. **If YES to #10, answer the following:**

Total number of acres to be acquired under proposal Not applicable to proposed project.
Number of acres to be acquired in fee Not applicable to proposed project.
Number of acres to be subject to conservation easement Not applicable to proposed project.

13. **For all proposals involving physical changes to the land or restriction in land use, describe what entity or organization will:**
    manage the property Not applicable to proposed project.
    provide operations and maintenance services Not applicable to proposed project.
    conduct monitoring Not applicable to proposed project.

14. **For land acquisitions (fee title or easements), will existing water rights also be acquired?**
Not applicable to proposed project.

15. **Does the applicant propose any modifications to the water right or change in the delivery of Water?**

____ **Yes**	<u>X</u>___ **No**

16. **If YES to #15, describe** <u>Not applicable to proposed project.</u>

OMB Approval No. 0348-0043

APPLICATION FOR FEDERAL ASSISTANCE

2. DATE SUBMITTED 15 May 2000		Applicant Identifier
1. TYPE OF SUBMISSION: Application ☐ Construction ☒ Non-Construction; Preapplication ☐ Construction ☒ Non-Construction	**3. DATE RECEIVED BY STATE**	State Application Identifier
	4. DATE RECEIVED BY FEDERAL AGENCY	Federal Identifier

5. APPLICANT INFORMATION

Legal Name: Michael Singer	Organizational Unit:
Address *(give city, county, State, and zip code)*: Donald Bren School of Environmental Science & Mgmt 4670 Physical Sciences North, UC Santa Barbara Santa Barbara CA 93106	Name and telephone number of person to be contacted on matters involving this application *(give area code)* Michael Singer (805) 893-8816

6. EMPLOYER IDENTIFICATION NUMBER *(EIN)*: ☐☐-☐☐☐☐☐☐☐

7. TYPE OF APPLICANT: *(enter appropriate letter in box)* L

A. State	H. Independent School Dist.
B. County	I. State Controlled Institution of Higher Learning
C. Municipal	J. Private University
D. Township	K. Indian Tribe
E. Interstate	L. Individual
F. Intermunicipal	M. Profit Organization
G. Special District	N. Other (Specify) ________

8. TYPE OF APPLICATION: ☒ New ☐ Continuation ☐ Revision

If Revision, enter appropriate letter(s) in box(es) ☐ ☐

A. Increase Award B. Decrease Award C. Increase Duration D. Decrease Duration Other*(specify)*:

9. NAME OF FEDERAL AGENCY: CALFED

10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: ☐☐-☐☐☐

TITLE:

11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT: Large-Scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology.

12. AREAS AFFECTED BY PROJECT *(Cities, Counties, States, etc.)*: Butte, Colusa, Glenn, Sacramento, Shasta, Sutter, Tehama and Yolo Counties in California

13. PROPOSED PROJECT		14. CONGRESSIONAL DISTRICTS OF:	
Start Date	Ending Date	a. Applicant	b. Project
2001	2003	22	2, 3, 5

15. ESTIMATED FUNDING:

a. Federal	$ 145,310 .00
b. Applicant	$ .00
c. State	$ .00
d. Local	$ .00
e. Other	$ .00
f. Program Income	$ .00
g. TOTAL	$ 145,310 .00

16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?

a. YES. THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON:

DATE ________

b. No. ☐ PROGRAM IS NOT COVERED BY E. O. 12372
☐ OR PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW

17. IS THE APPLICANT DELINQUENT ON ANY FEDERAL DEBT?

☐ Yes If "Yes," attach an explanation. ☒ No

18. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION/PREAPPLICATION ARE TRUE AND CORRECT, THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNING BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED ASSURANCES IF THE ASSISTANCE IS AWARDED.

a. Type Name of Authorized Representative: Michael Singer	b. Title: Researcher Scientist	c. Telephone Number: (805) 893-8816
d. Signature of Authorized Representative		e. Date Signed: 5/12/00

SECTION C - NON-FEDERAL RESOURCES

(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e) TOTALS
8.	$	$	$	$
9.				
10.				
11.				
12. TOTAL *(sum of lines 8-11)*	$	$	$	$

SECTION D - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 145,310	$ 36,327	$ 36,327	$ 36,327	$ 36,329
14. Non-Federal					
15. TOTAL *(sum of lines 13 and 14)*	$	$	$	$	$

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

(a) Grant Program	FUTURE FUNDING PERIODS (Years)			
	(b) First	(c) Second	(d) Third	(e) Fourth
16.	$ 145,310	$ 129,685	$ 124,985	$
17.				
18.				
19.				
20. TOTAL *(sum of lines 16-19)*	$ 145,310	$ 129,685	$ 124,985	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges:	22. Indirect Charges:
23. Remarks:	

BUDGET INFORMATION - Non-Construction Programs

OMB Approval No. 0348-0044

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1.		$	$	$	$	$
2.						
3.						
4.						
5. Totals		$	$	$	$	$

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY (1)	(2)	(3)	(4)	Total (5)
a. Personnel	$	$	$ 76,960	$	$ 76,960
b. Fringe Benefits			7,696		7,696
c. Travel			13,100		13,100
d. Equipment					
e. Supplies			27,150		27,150
f. Contractual			9,640		9,640
g. Construction					
h. Other					
i. Total Direct Charges *(sum of 6a-6h)*			134,546		134,546
j. Indirect Charges			10,764		10,764
k. TOTALS *(sum of 6i and 6j)*	$	$	$ 145,310	$	$ 145,310
7. Program Income	$	$	$	$	$

Authorized for Local Reproduction

OMB Approval No. 0348-0040

ASSURANCES - NON-CONSTRUCTION PROGRAMS

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0040), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant, I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of the United States and, if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§4728-4763) relating to prescribed standards for merit systems for programs funded under one of the 19 statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C. §§1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U.S.C. §§6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. §§290 dd-3 and 290 ee 3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §§3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and, (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally-assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a-7), the Copeland Act (40 U.S.C. §276c and 18 U.S.C. §874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally-assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. §§7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended (P.L. 93-523); and, (h) protection of endangered species under the Endangered Species Act of 1973, as amended (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. §470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. §§2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§4801 et seq.) which prohibits the use of lead-based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act Amendments of 1996 and OMB Circular No. A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations, and policies governing this program.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	TITLE
APPLICANT ORGANIZATION	**DATE SUBMITTED**
	15 May 2000

STATE OF CALIFORNIA

NONDISCRIMINATION COMPLIANCE STATEMENT

STD. 19 (REV. 3-95)

COMPANY NAME
Michael Singer

The company named above (herinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, physical disability (including HIV and AIDS), medical condition (cancer), age (over 40), marital status, denial of family care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.

OFFICIAL'S NAME
Michael Singer

DATE EXECUTED
5/12/00

EXECUTED IN THE COUNTY OF
Santa Barbara

PROSPECTIVE CONTRACTOR'S SIGNATURE

PROSPECTIVE CONTRACTOR'S TITLE

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME
Michael Singer